Structural Analysis & Bridge Load Rating Report

for

Kern Bridge

(formerly MnDOT Bridge No. L5669)

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Report Date August 31, 2017

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Minnesota Department of Transportation (MnDOT)
Kern Bridge Structural Analysis & Load Rating Report

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I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the state of Minnesota.

Joseph D. Litman
Signature

Joseph D. Litman
Printed Name

21833
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Executive Summary **Bridge Number: L5669**

The Kern Bridge (also known as former MnDOT Bridge L5669), is located in the southeast corner of South Bend Township and the southwest corner of Mankato Township in Blue Earth County. The bridge spans the Le Sueur River and is closed to vehicular and pedestrian traffic. Mankato Township owns the bridge. The Kern Bridge is unusual in that its 188-foot span length exceeds the standard lengths of 50 to 130 feet for bowstring truss/arch spans nationally. Constructed in 1873, the bridge is listed in the National Register of Historic Places (National Register) as the only example of a bowstring through-truss/arch bridge in Minnesota. It holds exceptional significance as the longest bowstring truss/arch in the United States and the second longest in North America.

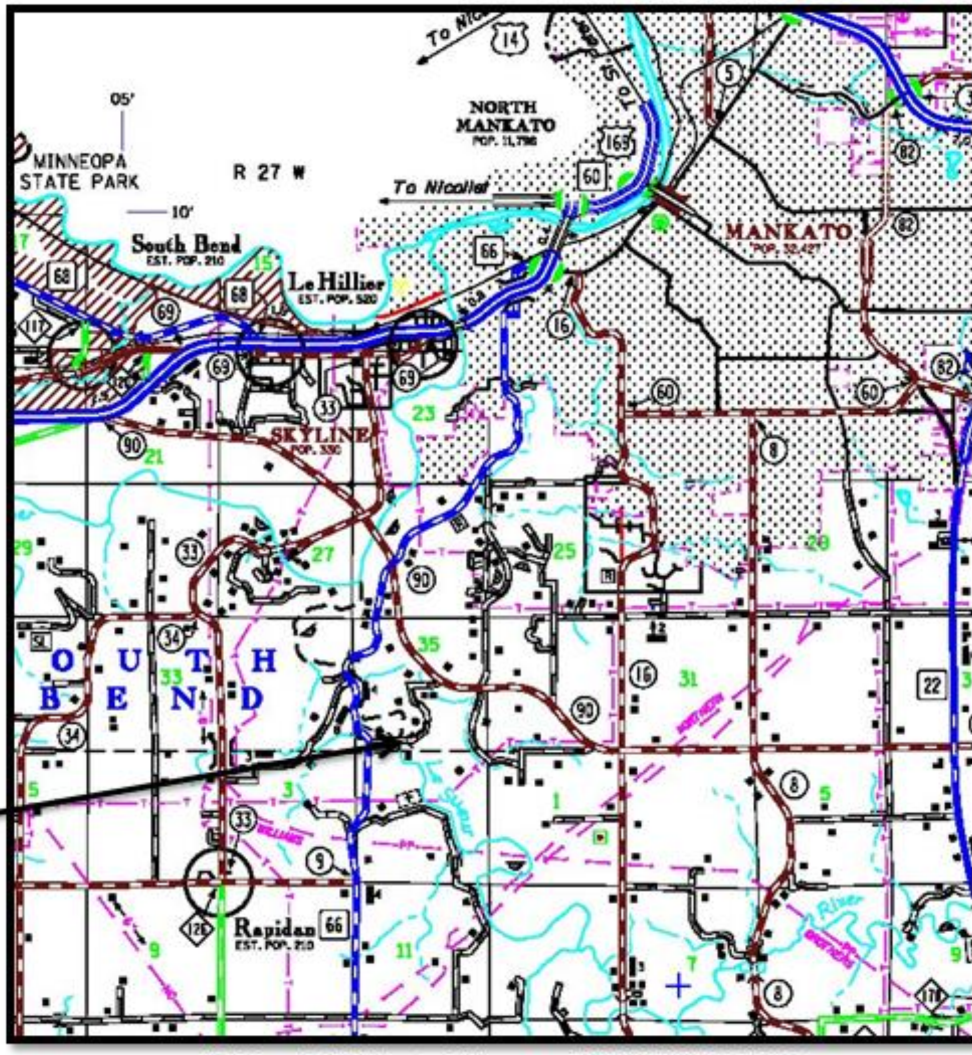
The Kern Bridge formerly carried Ivywood Lane (Township Road 190) over the Le Sueur River in Blue Earth County. The out-to-out width of the timber deck is 15 feet 10-inches and the clear width is 14 feet 9 inches between the timber curbs. The deck is about 30 feet above the riverbed. The abutments are stone masonry.

The Kern Bridge superstructure is in fair condition overall, its substructures (abutments) are in poor condition and it is currently closed to pedestrian and vehicular traffic. The rehabilitation opinions contained herein outline a process to disassemble the bridge and correct identified structural deficiencies to preserve the truss/arch once relocated to a new site.

As a Historic, National Register Listed structure and in order to maintain and preserve this status, work on The Kern Bridge would be required to proceed according to the Secretary of the Interior's Standards for the Treatment of Historic Properties (Standards) [36 CFR part 67] and *The Secretary's Standards with Regard to Repair, Rehabilitation, and Replacement Situations,* as adapted by the Virginia Transportation Research Council (Guidelines). This report contemplates relocating the structure to a new site which may be considered to not comply with the Standards. However, relocation may be the only alternative to preserve any portion of the structure if its remaining in place results in its total loss/collapse into the river.

Bridge Location **Bridge Number: L5669**

BR. NO. L5669



Bridge L5669 – T190 over LE SUEUR RIVER

PROJECT LOCATION
BLUE EARTH COUNTY
SEC. 35, TO 107NN, R 27W
UTM ZONE: 15 NAD: 27
USGS QUAD NAME: GOOD THUNDER
EASTING: 1366819 ft.
NORTHING: 16025539 ft.

I – Purpose of the Study **Bridge Number: L5669**

LHB was retained by the Minnesota Department of Transportation (MnDOT) to assist with structural analysis, load capacity rating, and relocation/rehabilitation opinion for the Kern Bridge in Blue Earth County, Minnesota.

The principal goals of this study are to assess the current condition of the Kern Bridge historic bowstring truss/arch superstructure elements, analyze the current bridge elements' structural capacities, calculate a bridge load rating based on pedestrian and maintenance vehicle use, and to provide an opinion of feasibility and preliminary cost estimates for relocation and rehabilitation of the bridge. It should also be noted that although the Kern Bridge is classified as a bowstring truss its structural geometrics and load paths function as a tied arch and for that reason it has been analyzed herein as a tied arch.

Rehabilitation opinions within this Report are intended to be consistent with the Secretary of the Interior's Standards for the Treatment of Historic Properties (Standards). The Standards are basic principles created to help preserve the distinct character of a historic property, while allowing for reasonable change to meet new engineering standards and codes. The Standards recommend repairing, rather than replacing deteriorated features whenever possible. The Standards apply to historic properties of all periods, styles, types, materials and sizes and encompass the property's location and surrounding environment.

The Standards were developed with historic buildings in mind and cannot be easily applied to historic bridges. The Virginia Transportation Research Council (Council) adapted the Standards to address the special requirements of historic bridges. They were published in the Council's 2001 Final Report: A Management Plan for Historic Bridges in Virginia, *The Secretary's Standards with Regard to Repair, Rehabilitation, and Replacement Situations,* provide useful direction for undertaking maintenance, repair, rehabilitation, and replacement of historic bridges and are included in the Appendix of this report.

Existing Conditions

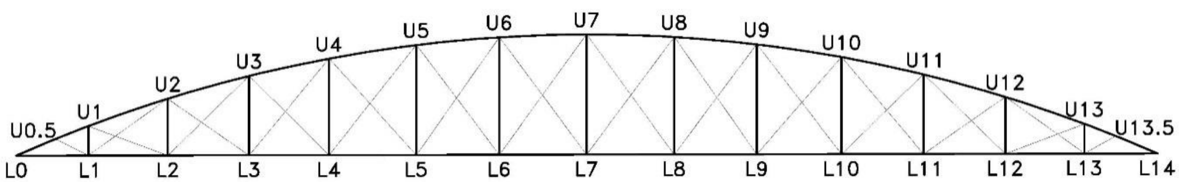
A site visit was conducted to establish the following:

1. General condition of structure
2. Bridge geometry, clearances and notable site issues
3. Geometrics for structural analysis

Superstructure

Wrought Iron Truss/Arch-Primary Members

The bottom chord tension members are in fair condition. Impact damage to the bottom chord members was noted in four locations on the south (upstream) truss/arch. The bottom chord splice plates are distorted from minor pack rust. The built-up top chord configuration is commonly referred to as a Phoenix Column (see Photo 8). The Phoenix Columns appeared in good condition with no significant defects noted. The built-up vertical members are in fair condition with minor pitting noted, especially near the connection to the lower chord. Some loss of section was noted at these locations, amounting to 5 percent or less loss of original section. The round stock diagonal members are in good to fair condition.



Fixed (West) **Expansion (East)**

Sketch 1: South Truss/Arch Elevation Looking North

Wrought Iron Truss/Arch-Portals and Secondary Members

Two of the portals on the west end of the truss/arch are damaged from impacts. Bolts are missing from the connections between the bottom chord and bracing members at several locations along the length of the bridge. The upper sway brace connection in the southeast corner of the bridge is broken. The X-bracing in the plane of the floor system is currently ineffective with the members mostly disconnected and hanging off the bridge.

Truss/Arch Floorbeams and Timber Stringers

The truss/arch floorbeams appeared to be in good to fair condition, though close examination was only possible at either end of the truss/arch (L1 and L13). The timber stringers that were accessible also appeared to be in good to fair condition.

Bridge Railings

A previous bridge railing appears to have been removed, as evidenced by hardware and brackets that remain on the structure. The two lines of wire rope that have been installed on each truss/arch to function as railings are in good condition, though the railing geometry and configuration does not meet current standards for either pedestrian/bikeway or vehicular traffic.

Paint System
The paint system has failed 100 percent on all metal portions of the bridge.

Timber Deck, Curbs, and Running Planks
The transverse timber deck planks are in fair condition, with approximately 30 individual planks requiring replacement due to damage and/or decay. The timber curbs are in fair condition with an estimated 30 linear feet of damaged or decayed curb requiring replacement. The longitudinal timber running planks are in poor condition and require 100 percent replacement. The existing broken and decayed running planks along with exposed nails and hardware present a serious tripping hazard that, coupled with the non-conforming railings, present a serious safety risk.

Bearings
Truss/arch bearings are non-functioning and mostly buried in earth. Movement of the truss/arch independent of the bearings has caused cracks and dislocation of the stone masonry at the east abutment.

Substructures

Abutments
The stone masonry abutments are in poor condition, especially the east abutment. The masonry at the east abutment is cracked and some of the stones are dislodged from their original position, particularly near the truss/arch supports where non-functioning expansion bearings have transmitted unintended lateral forces to the masonry. In addition, the foundation of the east abutment at the south end has settled, causing vertical translation of the bottom chord at this location. This condition may also be responsible for the broken sway brace connection in the southeast corner discussed in the “Wrought Iron Truss/Arch-Portal and Secondary Members” section above. The southeast slope has washed out, resulting in exposure of the stone masonry abutment back face. The west abutment has been underpinned in the past to correct undermining.

An independent support of the bottom chord consisting of a steel H-pile section supported on a concrete pad poured on the bedrock is present in the southwest corner. While it is unclear whether or not this rough shoring apparatus is actually supporting the truss/arch, it should be removed prior to subjecting the truss/arch to any significant live or dead loading. The location of the temporary support is far enough from the bearing location that it will introduce loading directions and magnitudes that the truss/arch is not designed to accommodate. Crippling of the bottom chord and collapse of the bridge is a likely scenario if the bridge is subjected to vehicular live loads with this support in place.

Date of Engineering Site Visit by LHB
April 29, 2014 & June 12, 2017

Photo 1: South elevation, looking north

Photo 2: East bridge approach, looking west

Photo 3: East approach, looking east

Photo 4: West approach, looking east

Photo 5: West approach, looking west

Photo 6: Typical bottom chord configuration

Photo 7: Bottom chord showing distortion of splice plates

Photo 8: Top chord configuration (Phoenix Column)

Photo 9: Typical latticed vertical member

Photo 10: Typical built-up vertical member (note previous railing hardware remaining)

Photo 11: End portals and sway braces

Photo 12: Floorbeams and timber stringers (note hanging X-bracing)

Photo 13: Missing bolt at secondary member connection (1 of 2)

Photo 14: Missing bolts at secondary member connection (2 of 2)

Photo 15: Timber deck (note uneven surface, potential tripping hazard)

Photo 16: Bearing at east abutment

Photo 17: East abutment masonry dislocation, southeast corner

Photo 18: East abutment masonry dislocation, northeast corner

Photo 19: West abutment

Photo 20: Truss/arch support in southwest corner

Photo 21: Typical bolted connection, vertical to bottom chord

Photo 22: Typical bolted connection, vertical to top chord

Photo 23: Southeast slope washout

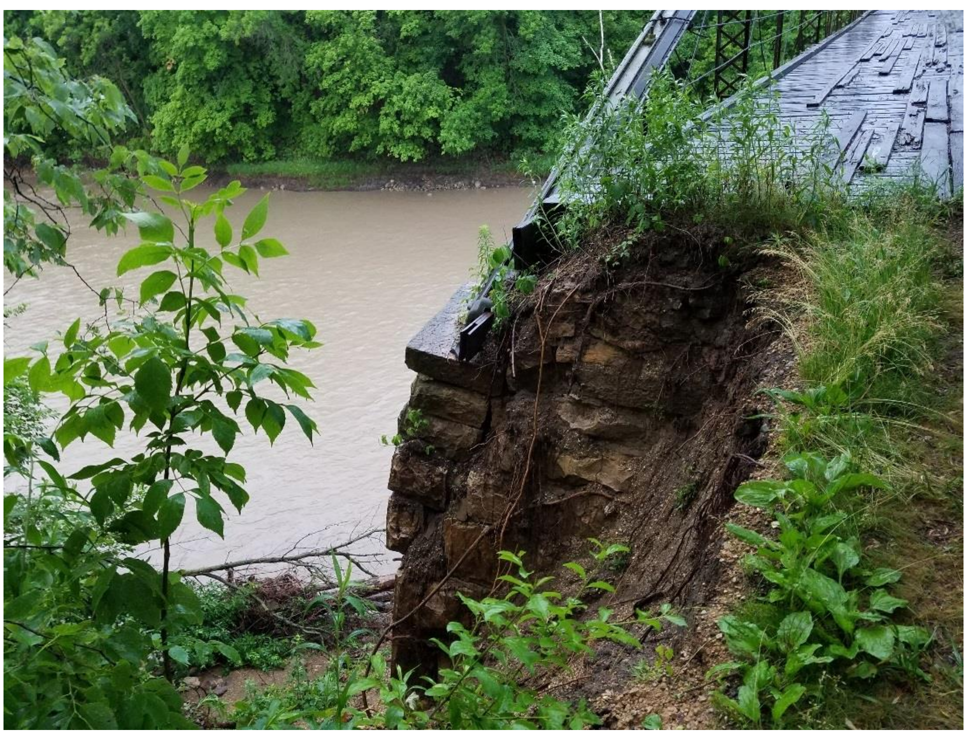


Photo 24: Southeast slope washout, exposed stone masonry abutment

III – Structural Analysis & Load Rating Bridge Number: L5669

The Kern Bridge truss/arch and floor beams were analyzed and rated for safe load carrying capacity in conformance with The Manual for Bridge Evaluation, 2nd Edition, 2011, and Standard Specifications for Bridges, 17th Edition, 2002, published by AASHTO. The analysis concentrated on the truss/arch top chord, bottom chord and transverse floor beams using Load Factor Rating (LFR) methodology. The timber deck and timber stringers were not analyzed for capacity and rating purposes as it is assumed the entire system will need to be replaced if the structure is relocated. If relocated, a more detailed analysis/ design of the timber deck and timber stringers would need to be completed.

All truss/arch elements were analyzed utilizing AASHTO pedestrian and maintenance vehicle loading with 5 percent overall loss of section to account for rust and other noted deficiencies. Per AASHTO the pedestrian (85 PSF) and H10 maintenance vehicle live loads are not analyzed as a combined load case unless an existing traffic barrier is in place between designated vehicular and pedestrian travel ways. The bridge does not include a barrier separating pedestrian and vehicular travel ways, therefore two different live load cases were used to determine whether pedestrian or vehicular live loading controlled the analysis. It was assumed that the future use of the bridge is to be a pedestrian structure, therefore impact was not applied to the live loads. The dead load of the bridge was calculated from field measurements of the current bridge structure.

One side of the truss/arch (south side) was modeled using structural analysis software (RISA-3D Version 15.0.2) to aid in determining stress levels for the structure. The top chord was modeled for compression only and the bottom chord as tension only members due to the nature of the bowstring truss/arch design. Bending induced in the top chord from the applied loads, of the vertical and diagonal members, was also considered in the analysis. The floorbeams were analyzed as a simply supported beam.

The table below (Figure 1) reflects analysis of the bridge in its current state, using pedestrian and H10 maintenance vehicle live loading. Based on our knowledge of the bridge's history and the date it was built, we assumed all floorbeams and truss/arch elements of the bridge to be wrought iron, therefore yield and ultimate stresses of 26 KSI and 48 KSI respectively were used for all floorbeams and truss/arch members in our analysis. Note that a rating factor of 1.0 means the design live load capacity is equivalent to the applied design load.

Bridge Element	**Inventory Rating Factor**	**Operating Rating Factor**	**Controlling Limit State** *(Live Load Case)*
Truss/Arch Top Chord	0.32	0.53	Ultimate Compression + Bending *(Pedestrian loading)*
Truss/Arch Bottom Chord	0.78	1.30	Ultimate Tension *(Pedestrian loading)*
Floorbeam	0.05	0.08	Ultimate Bending *(H10 loading)*

Figure 1: Rating factor summary of all analyzed bridge elements for current state

With the bridge in its current state, the analysis indicates that it is not capable of supporting the applied pedestrian or H10 maintenance vehicle live loads. Based on the era of when the bridge was designed, it is assumed that the maximum load it was designed to carry was a horse and buggy type vehicle, which is much lighter when compared to the applied live loads used in this analysis. It is also assumed that the top chord was originally designed for pure axial compression only (a simplification, though unconservative) and that the effects of combined axial load and bending would not have been considered. The floorbeam rating factors are very low compared to the truss/arch chord members, as summarized in Figure 1, thus controlling the bridge load rating. Options for rehabilitation/ renovation were explored to determine if the structure could be modified to safely carry the applied loads. For rehabilitation purposes, a minimum inventory rating factor of 0.90 was assumed for any bridge element to be considered adequate for carrying the applied loads.

The truss/arch top and bottom chord rating factors were controlled by the pedestrian live load case. The first option (Option 1) explored for improving the top and bottom chord rating factors, was to reduce the timber deck clear width in order to lessen the applied pedestrian live load. The current clear width is 14 feet 9 inches. The analysis concluded that the timber deck clear roadway width between railings would need to reduce to approximately 7 feet, centered on the floor beams, to achieve a minimum 0.90 inventory rating factor. The second option (Option 2), included reducing the timber deck clear width in combination with adding lateral bracing members at upper panel points U1, U2, U12 and U13 to minimize the top chord unbraced length. Lateral bracing could potentially be added to these panel points by framing to the floorbeams on the interior side of the bridge. For this option, the analysis allowed for the timber deck to be reduced to approximately 10 feet clear width between railings. Due to the reduced clear roadway widths of 7 to 10 feet, H5 maintenance vehicle live loading was used instead of the H10 maintenance vehicle per the AASHTO: LRFD Guide Specifications for the Design of Pedestrian Bridges, 2009 with 2015 Interim Revisions. However, even if H10 maintenance vehicle loading were used, pedestrian loading would remain the controlling limit state for all cases in Figure 2. A summary of the top and bottom chord rating factors for each reduced timber deck width (Options 1 and 2) can be found in Figure 2, floorbeam not included.

Rating Factor Summary: pedestrian (85 PSF) or H5 or H10 maintenance vehicle loading				
Option	**Bridge Element**	**Inventory Rating Factor**	**Operating Rating Factor**	**Controlling Limit State** *(Live Load Case)*
1	Truss/Arch Top Chord *(7' clear width)*	0.97	1.61	Ultimate Compression + Bending *(Pedestrian loading)*
1	Truss/Arch Bottom Chord *(7' clear width)*	1.98	3.31	Ultimate Tension *(Pedestrian loading)*
2	Truss/Arch Top Chord *(10' clear & added bracing)*	0.92	1.22	Ultimate Compression + Bending *(Pedestrian loading)*
2	Truss/Arch Bottom Chord *(10' clear & added bracing)*	1.33	2.22	Ultimate Tension *(Pedestrian loading)*

Figure 2: Rating factor summary of top and bottom chord rehabilitation for Options 1 and 2

A third option explored (Option 3) sought to maintain existing bridge width to the greatest extent practical with an acknowledgement that doing so would require a design exception to allow for a reduction in the design pedestrian live load. This has been done on previous historic bridge projects where it is determined known use of the bridge combined with load posting can achieve safe usage of the structure. For this option, a reduced design pedestrian load of 45 PSF was used. Note that for this option lateral bracing members will also be required at upper panel points U1, U2, U12 and U13 to minimize the top chord unbraced length. Lateral bracing could potentially be added to these panel points by framing to the floorbeams on the interior or exterior side of the bridge.

Rating Factor Summary: pedestrian (45 PSF - *reduced*) or H5 or H10 maintenance vehicle loading				
Option	**Bridge Element**	**Inventory Rating Factor**	**Operating Rating Factor**	**Controlling Limit State** *(Live Load Case)*
3	Truss/Arch Top Chord *(approx. existing clear width)*	0.93	1.55	Ultimate Compression + Bending *(Pedestrian loading - reduced)*
3	Truss/Arch Bottom Chord *(approx. existing clear width)*	1.47	2.45	Ultimate Tension *(Pedestrian loading - reduced)*

Figure 3: Rating factor summary of top and bottom chord rehabilitation for Option 3

Due to the very low rating factor values of the existing floor beams, two options for replacing the existing floorbeams were considered. The reduced timber deck widths used in the top and bottom chord analysis were used when determining applied loading to the proposed floorbeams. The first option considered was to determine a similar steel rolled shape section that could be used instead of the current section. W- or S-shapes were chosen due to their similar proportionality of depth-to-width ratio when compared to the current beam shape, measured at 8-inches deep with a 3-3/8-inch-wide flange. Steel yield stress of 36 KSI was used for S-shapes and 50 KSI was used for W-shapes for analysis. The second option explored was to fabricate built-up steel I-shaped sections, using the same criteria of proportionality to preserve the look and feel of the existing beams. Due to a wide variety of options for built-up section geometrics, it was determined that if using a built-up shape was the preferred option, the geometrics should be determined at the time of design in collaboration with a historic review and would not be further considered in this study. For the purposes of this study, only W- or S-shape sections were considered when analyzing rating factor results for the proposed floorbeams options. A summary of the proposed floorbeams and their respective rating factors can be found in Figure 4. In all floorbeam cases pedestrian live loading controls in the ultimate bending limit state when compared to the H5 maintenance vehicle live loading.

Rating Factor Summary: pedestrian or H5 maintenance vehicle loading				
Option	**Reduced Timber Deck Width Configuration**	**Floorbeam Shape**	**Inventory Rating Factor**	**Operating Rating Factor**
1	7' clear bridge deck width *(Pedestrian loading – 85 PSF)*	W8X28	1.05	1.76
		S10X35	0.98	1.64
2	10' clear bridge deck width *(Pedestrian loading – 85 PSF)*	W12X35	1.19	1.99
		S12X40.8	1.21	2.03
3	Existing bridge deck width *(Pedestrian loading – 45 PSF)*	W8X28	1.11	1.85
		S10X35	1.02	1.70

Figure 4: Rating factor summary of proposed floorbeams for rehabilitation

If the H10 maintenance vehicle live load is considered in the rating factor analysis for the 10-foot clear bridge deck width option, the rating factors decrease due to the increased maintenance vehicle loading when compared to the H5 maintenance vehicle live loading. A summary of the proposed floorbeams and their respective rating factors for the H10 maintenance vehicle can be found in Figure 5.

Rating Factor Summary: H10 maintenance vehicle loading				
Option	**Reduced Timber Deck Width Configuration**	**Floorbeam Shape**	**Inventory Rating Factor**	**Operating Rating Factor**
2	10' clear bridge deck width *(H10 loading)*	W12X35	0.94	1.57
		S12X40.8	0.96	1.59
3	Existing bridge deck width *(H10 loading)*	W12X35	0.90	1.50
		S12X40.8	0.92	1.53

Figure 5: Rating factor summary of proposed floorbeams for rehabilitation

Overall Rehabilitation Opinion

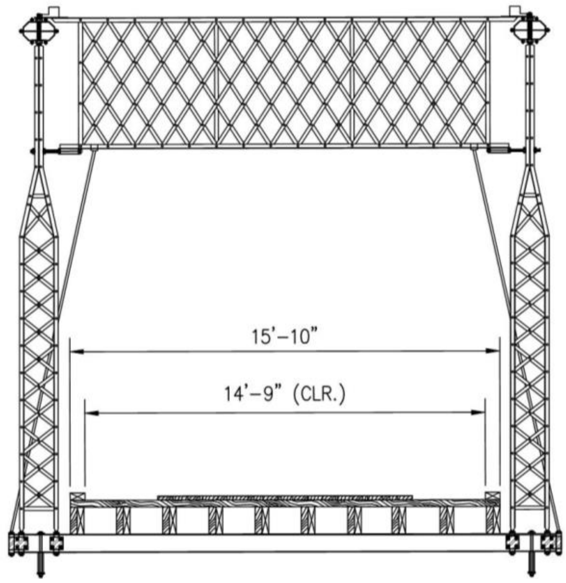
The bridge is currently closed to vehicular and pedestrian traffic due to its deteriorated condition, low load carrying capacity, deficient geometry and closure of the township road the bridge previously carried. The east approach is heavily vegetated. An earth berm, together with a plate beam traffic barrier are in place to prevent vehicular use. The west approach has been removed altogether and is now residential private property. A failed wooden fence is present at the west approach, leaving the west end of the bridge un-barricaded. Signs of use of the bridge by pedestrians was observed at the time of the site visit and signs prohibiting such use were not evident. The bridge owner has indicated that there are no plans to reopen the bridge to vehicular or pedestrian traffic.

The southeast slope wash out, poses concern to the stability of the bridge substructure and possible failure or collapse of the bowstring truss/arch superstructure. The approximate timing of the wash out is believed to have occurred in September of 2016; based on LHB site visits within recent years and historical water level and flow data obtained from the United States Geological Survey (USGS) National Water Information System, per measuring instrument located on the Kern Bridge. Though, the bridge and abutment appeared to be stable at the time of LHB's most recent site visit, June 12, 2017, it is highly unpredictable to know when the next rain or flood event may occur, possibly resulting in further erosion of the bridge slopes. Thus, the susceptibility to further erosion at the east abutment during high flow events and unknown depth and footing bearing condition for the abutment makes the continued stability of the bridge from collapse unpredictable. One option to help stabilize the slopes could be to place riprap along the southeast slope to help protect from further erosion. For purposes of this study, no cost has been associated with placing riprap at the current bridge location.

The rehabilitation opinions that follow assume the bridge will be dismantled and reassembled at a different location and used for pedestrian purposes. The nature of the original bridge construction, with mainly bolted connections, lends itself well to disassembly and relocation although the sheer size and remote setting/location would make for a difficult task. Should this course of action be considered, the historic impacts (adverse effect of relocation) of such a move would have to be weighed with potential outcomes should the bridge remain in place and be unable to be preserved or maintained or even collapse due to abutment failure.

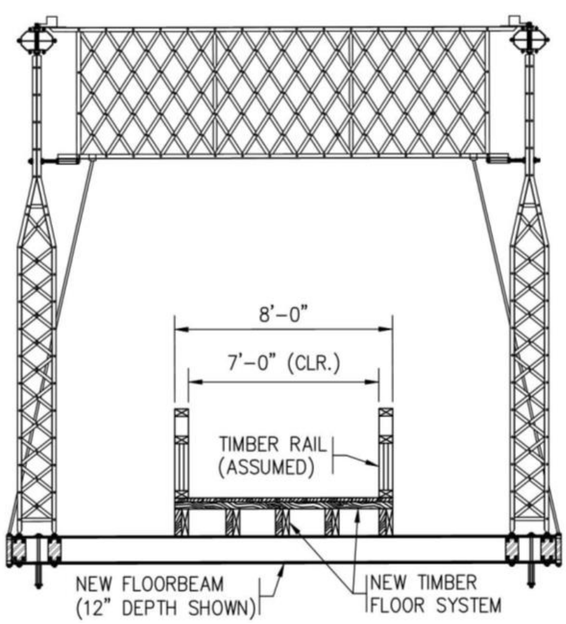
Three potential rehabilitative options have been considered for the bridge to allow for safe load carrying capacity under pedestrian and maintenance vehicle live loading once dismantled and reassembled at a different location. Options 1 and 2 propose to modify the clear width of the deck. See Sketch 2 below for the existing deck section. The proposed deck sections for Options 1 and 2 are represented by Sketches 3 and 4, respectively. Option 3 proposes using design exceptions reducing the magnitude of the applied pedestrian loading to maintain the existing clear width of the deck. See Sketches 5 and 6 for details. Any reduction of pedestrian design loading should be determined through a collaboration between the bridge engineer, bridge owner and project funding entity.

A fourth "interim" option has been considered allowing for the bowstring arch/truss superstructure to be dismantled and stored until a project for relocation and reuse may be established.



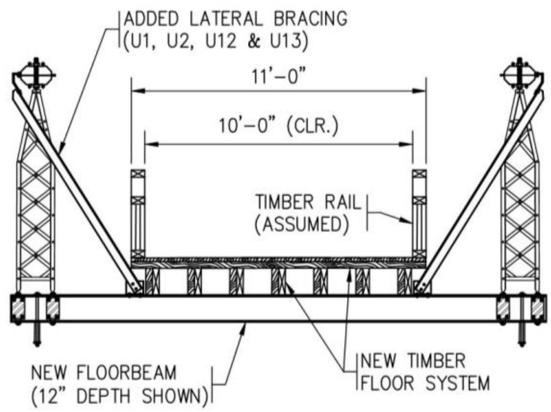
Sketch 2: Existing deck section (shown at panel points L6-U6)

Option 1: Dismantle, straighten, blast/paint and reassemble structure at different location as detailed/ discussed in the Structure Relocation section on page 23. Replace existing floorbeams with new steel rolled section or built-up shape. Remove and replace timber floor system (i.e. stringers, transverse deck planks, running planks and curbs) in their entirety. Replaced timber floor system to include a reduced clear bridge deck width of approximately 7 feet with an added railing system conforming with future intended use. Additional work to complete the preservation is further discussed in the Option 1 discussion on page 23.



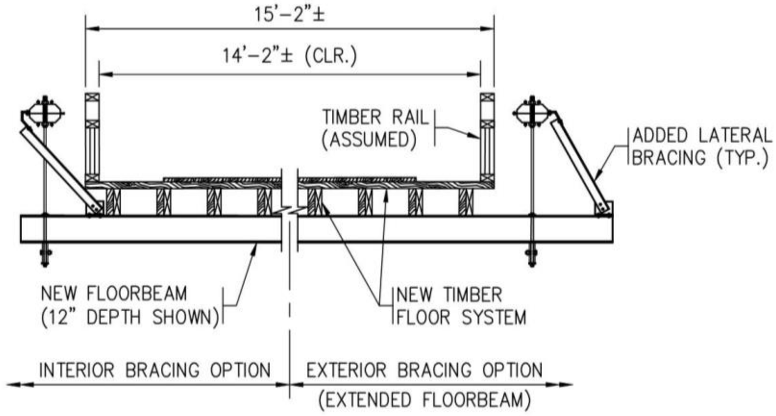
Sketch 3: Proposed deck section for Option 1 (shown at panel points L6-U6)

Option 2: Dismantle, straighten, blast/paint and reassemble structure at different location as detailed/ discussed in the Structure Relocation section on page 23. Add lateral bracing members to unbraced panel points at beginning and end of top chord. Replace existing floorbeams as detailed/discussed for Option 1. Remove and replace timber floor system (i.e. beams, transverse deck planks, running boards and curbs) in their entirety. Replaced timber floor system to include a reduced clear bridge deck width of approximately 10 feet with an added railing system conforming with future intended use. Additional work to complete the preservation is further discussed in the Option 2 discussion on page 23.

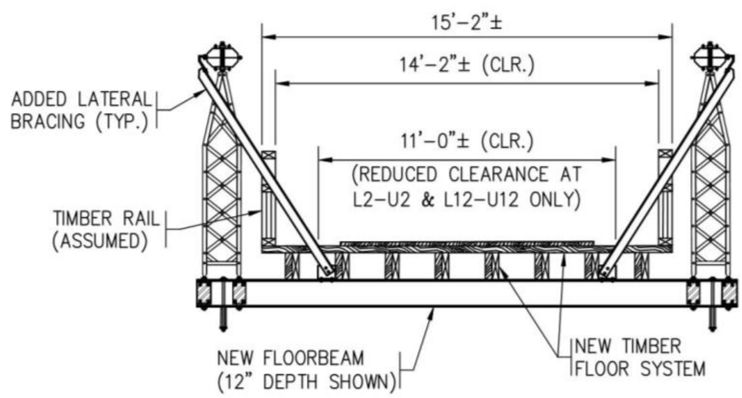


Sketch 4: Proposed deck section for Option 2
(shown at panel points L2-U2; L1-U1, L12-U12 and L13-U13 similar)

Option 3: Dismantle, straighten, blast/paint and reassemble structure at different location as detailed/ discussed in the Structure Relocation section on page 23, including gaining a design exception for reduced pedestrian live loading. Add lateral bracing members to unbraced panel points at beginning and end of top chord. Replace existing floorbeams as detailed/discussed for Option 1. Remove and replace timber floor system (i.e. beams, transverse deck planks, running boards and curbs) in their entirety. Replaced timber floor system to include a similar clear bridge deck width to the existing deck section, and an added railing system conforming with future intended use. Additional work to complete the preservation is further discussed in the Option 3 discussion on page 24.



Sketch 5: Proposed deck section for Option 3 (shown at panel points L1-U1; L13-U13 similar)



Sketch 6: Proposed deck section for Option 3 (shown at panel points L2-U2; L12-U12 similar)

Structure Relocation

For each option discussed below, the bridge should be partially dismantled on site and shipped to a steel fabrication/paint shop for straightening/repair, blasting and painting. The nature of the truss/arch construction should permit sufficient disassembly to allow for transportation without having to separate the individual components of the riveted built up members (channels, lacing, batten plates, etc.). Prior to disassembly, all truss/arch members must be carefully match-marked to ensure the reassembly exactly matches the original.

Option 1: Relocate bridge, replace floorbeams, and replace floor system (7-foot bridge deck clear width)

Discussion: For this option, complete dismantling, repair and relocation of the bridge as discussed in the Structure Relocation section above is assumed. It replaces the existing floorbeams with new steel rolled sections. As a result of using new floorbeams, it is assumed that existing wrought iron plates, and pins and hanger assemblies connecting the current floorbeams to the bottom chord will need to be replaced in order to accommodate the new beam shape. Replacement plates, and pin and hanger assemblies should be provided with new steel elements that match the geometry of the original elements. The timber floor system replacement would include similar size beams, transverse deck planks and running boards as the current system. Based on analysis of the existing structure, the new deck clear width is to be constructed to approximately 7 feet. This decreased width should allow for the existing truss/arch top and bottom chords to be reinstalled without structural capacity modifications.

Additional work items with this rehabilitation option would include: new reinforced concrete abutments (reinforced concrete assumed versus in-place stone masonry), approach grading, erosion control (i.e. granular filter, fabric, riprap), replace damaged sway braces, replace floor system cross bracing, replace fixed and expansion bearings (with new components of like material and geometry) and new timber railings along both sides of the new timber floor system.

Option 2: Relocate bridge, replace floorbeams, add lateral bracing, and replace floor system (10-foot bridge deck clear width)

Discussion: For this option, complete dismantling, repair and relocation of the bridge as discussed in the Structure Relocation section above is assumed. It replaces the existing floorbeams and bottom chord connection components as discussed in Option 1 above. It includes the addition of lateral bracing members at upper panel points U1, U2, U12 and U13. It is assumed that the added lateral bracing could be connected from the designated upper panel points to the new floorbeams (reduced width floor system allows for floorbeam exposure between trusses/arches and new deck edges). Thus, providing adequate bracing to increase the load rating of the element to an acceptable level. The timber floor system replacement would include similar size beams, transverse deck planks and running boards as the current system. Based on analysis of the existing structure, the new deck clear width is to be constructed to approximately 10 feet. This decreased width should allow for the existing truss/arch top and bottom chords to be reinstalled in conjunction with the added lateral bracing without structural capacity modifications to the chord.

Additional work for this option would be the same as additional work discussed for Option 1.

Option 3: Relocate bridge, replace floorbeams, add lateral bracing, replace floor system, and gain design exception for reduced pedestrian live loading (bridge deck clear width similar to existing except for reduction to 11-foot at panel points L2-U2 and L12-U12)

Discussion: For this option, complete dismantling, repair and relocation of the bridge as discussed in the Structure Relocation section is assumed. It replaces the existing floorbeams and bottom chord connection components as discussed in Option 1. It includes the addition of lateral bracing members at upper panel points U1, U2, U12 and U13. It is assumed that the added lateral bracing could be connected from the upper panel points to the new floorbeams by either extending the floorbeams beyond the exterior truss/arch face and connecting to the exterior side of the bridge, or by connecting to the floorbeams on the interior side of the bridge by penetrating the deck (see Sketches 5 and 6). Note that the new bracing as shown in Sketch 6 will require a localized bridge deck width decrease at panel points U2 and U12 to facilitate an efficient angle for the top chord braces. An additional option at this location could be to provide a structural steel railing system to brace to, in lieu of a timber railing system. For purposes of this study, a structural steel railing system has not been considered. The timber floor system replacement would include similar size beams, transverse deck planks, running boards and overall clear width dimension as the current system. Based on analysis of the existing structure, design exceptions would need to be considered to reduce the magnitude of the applied pedestrian loading to allow for the existing bridge width to be used. The decreased applied pedestrian loading should allow for the existing truss/arch top and bottom chords to be reinstalled in conjunction with the added lateral and sway bracing without structural capacity modifications to the chord.

Additional work for this option would be the same as additional work discussed for Option 1.

Option 4: Remove/ disassemble bridge from existing location and ship to off-site location for storage.

Discussion: Prior to disassembly, all truss/arch members must be carefully match-marked to ensure the reassembly exactly matches the original. The nature of the truss/arch construction should permit sufficient disassembly to allow for transportation without having to separate the individual components of the riveted built up members (channels, lacing, batten plates, etc.). One method for disassembly is to utilize the use of backstays erected at each end of the bridge to allow for the bridge to be dismantled beginning at the center of the bridge and progressing towards each abutment, and maintain bridge stability during disassembly. A second method to dismantle the bridge is to utilize an adequate crane(s) with the aid of engineered rigging to move the bridge onto temporary supports, and disassembling the bridge on land. For estimating purposes, the second option stated above, with use of two cranes, is to be considered. Once disassembled, all members are to be shipped to an off-site location for storage. All truss/arch members shall be stored in a manner such that no further damage or deformation will be sustained to the members including protection from further corrosion.

Option Cost Estimate Summary:
Itemized cost estimates for the rehabilitation options have been prepared and follow this discussion. The estimated construction costs as detailed within the estimates are as follows:

Option 1: Relocate Bridge, Replace Floorbeams, and Replace Floor System
(7-foot bridge deck clear width):
Est. Cost: $ 1,103,550.00

Option 2: Relocate Bridge, Replace Floorbeams, add Lateral Bracing, and Replace Floor System
(10-foot bridge deck clear width):
Est Cost: $ 1,191,400.00

Option 3: Relocate Bridge, Replace Floorbeams, add Lateral Bracing, and Replace Floor System
(bridge deck clear width similar to existing except for reduction to 11-foot at panel points L2-U2 and L12-U12) (Reduced Pedestrian Live Load):
Est Cost: $ 1,243,790.00

Option 4: Remove/ disassemble bridge from existing location and ship to off-site location for storage:
Est Cost: $ 271,000.00

Option 1: Relocate Bridge, Replace Floorbeams, and Replace Floor System (7-foot bridge deck clear width)

KERN BRIDGE, REHABILITATION OPTION STUDY ESTIMATE (2017 DOLLARS)
OPTION 1: RELOCATE BRIDGE, REPLACE FLOORBEAMS, AND REPLACE FLOOR SYSTEM (7-FOOT BRIDGE DECK CLEAR WIDTH)
August 31, 2017

			ESTIMATED QUANTITIES AND COST		
ITEM NO.	ITEM	UNIT	QUANTITY	UNIT COST	TOTAL ESTIMATE
	OPTION 1: RELOCATE BRIDGE, REPLACE FLOORBEAMS, AND REPLACE FLOOR SYSTEM (7 FT. CLR.)				
1	MOBILIZATION	LUMP SUM	1	$75,000.00	$75,000.00
2	DISMANTLE TRUSS/ARCH AND SHIP TO FAB SHOP	LUMP SUM	1	$165,000.00	$165,000.00
3	STRAIGHTEN LOWER CHORD MEMBERS	EACH	4	$5,250.00	$21,000.00
4	STRAIGHTEN SWAY BRACES	EACH	2	$2,750.00	$5,500.00
5	REPLACE IN PLACE FLOOR X-BRACING	LUMP SUM	1	$40,000.00	$40,000.00
6	REPLACE SWAY BRACES	EACH	2	$11,000.00	$22,000.00
7	REPLACE STEEL FLOORBEAMS	LIN FT	260	$110.00	$28,600.00
8	BLAST AND PAINT (SHOP)	SQ FT	7700	$15.00	$115,500.00
9	REPLACE BEARINGS IN KIND	EACH	4	$5,500.00	$22,000.00
10	REPLACE TIMBER STRINGERS	EACH	70	$500.00	$35,000.00
11	REPLACE TIMBER DECK PLANKS	SQ FT	1520	$25.00	$38,000.00
12	REPLACE TIMBER RUNNING PLANKS (2X6 NOM.)	LIN FT	2470	$8.00	$19,760.00
13	REPLACE TIMBER CURBS	LIN FT	380	$10.50	$3,990.00
14	NEW RAILING AT NEW SITE (TIMBER ASSUMED)	LIN FT	420	$45.00	$18,900.00
15	NEW CONCRETE ABUTMENTS AT NEW SITE	EACH	2	$55,000.00	$110,000.00
16	TRUCKING OF COMPONENTS TO NEW SITE	LUMP SUM	1	$15,000.00	$15,000.00
17	REASSEMBLE/ ERECT BRIDGE SUPERSTRUCTURE	LUMP SUM	1	$100,000.00	$100,000.00
18	COMMON EXCAVATION	CU YD	650	$18.00	$11,700.00
19	SELECT GRANULAR BORROW MOD 7%	CU YD	250	$32.00	$8,000.00
20	CLASS V AGGREGATE BASE	CU YD	300	$42.00	$12,600.00
21	EROSION CONTROL ETC	LUMP SUM	1	$20,000.00	$20,000.00
22	NEW BRIDGE SIGNAGE	LUMP SUM	1	$2,000.00	$2,000.00
23	SITE WORK AND RESTORATION AT OLD LOCATION	LUMP SUM	1	$30,000.00	$30,000.00
	20% CONTINGENCY	LUMP SUM	1	$184,000.00	$184,000.00
	ESTIMATED REHABILITATION COST				**$1,103,550.00**

Option 2: Relocate Bridge, Replace Floorbeams, add Lateral Bracing, and Replace Floor System (10-foot bridge deck clear width)

KERN BRIDGE, REHABILITATION OPTION STUDY ESTIMATE (2017 DOLLARS)
OPTION 2: RELOCATE BRIDGE, REPLACE FLOORBEAMS, ADD LATERAL BRACING, AND REPLACE FLOOR SYSTEM (10-FOOT BRIDGE DECK CLEAR WIDTH)
August 31, 2017

			ESTIMATED QUANTITIES AND COST		
ITEM NO.	ITEM	UNIT	QUANTITY	UNIT COST	TOTAL ESTIMATE
	OPTION 2: RELOCATE BRIDGE, REPLACE FLOORBEAMS, ADD LATERAL BRACING, AND REPLACE FLOOR SYSTEM (10 FT. CLR.)				
1	MOBILIZATION	LUMP SUM	1	$75,000.00	$75,000.00
2	DISMANTLE TRUSS/ARCH AND SHIP TO FAB SHOP	LUMP SUM	1	$165,000.00	$165,000.00
3	STRAIGHTEN LOWER CHORD MEMBERS	EACH	4	$5,250.00	$21,000.00
4	STRAIGHTEN SWAY BRACES	EACH	2	$2,750.00	$5,500.00
5	REPLACE IN PLACE FLOOR X-BRACING	LUMP SUM	1	$40,000.00	$40,000.00
6	REPLACE SWAY BRACES	EACH	2	$11,000.00	$22,000.00
7	REPLACE STEEL FLOORBEAMS	LIN FT	260	$110.00	$28,600.00
8	CONSTRUCT LATERAL BRACING MEMBERS (U1, U2, U12 & U13)	EACH	8	$4,500.00	$36,000.00
9	BLAST AND PAINT (SHOP)	SQ FT	7700	$15.00	$115,500.00
10	REPLACE BEARINGS IN KIND	EACH	4	$5,500.00	$22,000.00
11	REPLACE TIMBER STRINGERS	EACH	100	$500.00	$50,000.00
12	REPLACE TIMBER DECK PLANKS	SQ FT	2090	$25.00	$52,250.00
13	REPLACE TIMBER RUNNING PLANKS (2X6 NOM.)	LIN FT	3420	$8.00	$27,360.00
14	REPLACE TIMBER CURBS	LIN FT	380	$10.50	$3,990.00
15	NEW RAILING AT NEW SITE (TIMBER)	LIN FT	420	$45.00	$18,900.00
16	NEW CONCRETE ABUTMENTS AT NEW SITE	EACH	2	$55,000.00	$110,000.00
17	TRUCKING OF COMPONENTS TO NEW SITE	LUMP SUM	1	$15,000.00	$15,000.00
18	REASSEMBLE/ ERECT BRIDGE SUPERSTRUCTURE	LUMP SUM	1	$100,000.00	$100,000.00
19	COMMON EXCAVATION	CU YD	650	$18.00	$11,700.00
20	SELECT GRANULAR BORROW MOD 7%	CU YD	250	$32.00	$8,000.00
21	CLASS V AGGREGATE BASE	CU YD	300	$42.00	$12,600.00
22	EROSION CONTROL ETC	LUMP SUM	1	$20,000.00	$20,000.00
23	NEW BRIDGE SIGNAGE	LUMP SUM	1	$2,000.00	$2,000.00
24	SITE WORK AND RESTORATION AT OLD LOCATION	LUMP SUM	1	$30,000.00	$30,000.00
	20% CONTINGENCY	LUMP SUM	1	$199,000.00	$199,000.00
	ESTIMATED REHABILITATION COST				**$1,191,400.00**

Option 3: Relocate Bridge, Replace Floorbeams, add Lateral Bracing, and Replace Floor System (bridge deck clear width similar to existing except for reduction to 11-foot at panel points L2-U2 and L12-U12) (Reduced Pedestrian Live Load)

KERN BRIDGE, REHABILITATION OPTION STUDY ESTIMATE (2017 DOLLARS)
OPTION 3: RELOCATE BRIDGE, REPLACE FLOORBEAMS, ADD LATERAL BRACING, AND REPLACE FLOOR SYSTEM (BRIDGE DECK CLEAR WIDTH SIMILAR TO EXISTING)
August 31, 2017

			ESTIMATED QUANTITIES AND COST		
ITEM NO.	ITEM	UNIT	QUANTITY	UNIT COST	TOTAL ESTIMATE
OPTION 3: RELOCATE BRIDGE, REPLACE FLOORBEAMS, ADD LATERAL BRACING, AND REPLACE FLOOR SYSTEM (EXIST'G WIDTH)					
1	MOBILIZATION	LUMP SUM	1	$75,000.00	$75,000.00
2	DISMANTLE TRUSS/ARCH AND SHIP TO FAB SHOP	LUMP SUM	1	$165,000.00	$165,000.00
3	STRAIGHTEN LOWER CHORD MEMBERS	EACH	4	$5,250.00	$21,000.00
4	STRAIGHTEN SWAY BRACES	EACH	2	$2,750.00	$5,500.00
5	REPLACE IN PLACE FLOOR X-BRACING	LUMP SUM	1	$40,000.00	$40,000.00
6	REPLACE SWAY BRACES	EACH	2	$11,000.00	$22,000.00
7	REPLACE STEEL FLOORBEAMS	LIN FT	270	$110.00	$29,700.00
8	CONSTRUCT LATERAL BRACING MEMBERS (U1 & U13)	EACH	4	$3,500.00	$14,000.00
9	CONSTRUCT LATERAL BRACING MEMBERS (U2 & U12)	EACH	4	$5,500.00	$22,000.00
10	BLAST AND PAINT (SHOP)	SQ FT	7900	$15.00	$118,500.00
11	REPLACE BEARINGS IN KIND	EACH	4	$5,500.00	$22,000.00
12	REPLACE TIMBER STRINGERS	EACH	126	$500.00	$63,000.00
13	REPLACE TIMBER DECK PLANKS	SQ FT	2900	$25.00	$72,500.00
14	REPLACE TIMBER RUNNING PLANKS (2X6 NOM.)	LIN FT	3800	$8.00	$30,400.00
15	REPLACE TIMBER CURBS	LIN FT	380	$10.50	$3,990.00
16	NEW RAILING AT NEW SITE (TIMBER)	LIN FT	420	$45.00	$18,900.00
17	NEW CONCRETE ABUTMENTS AT NEW SITE	EACH	2	$55,000.00	$110,000.00
18	TRUCKING OF COMPONENTS TO NEW SITE	LUMP SUM	1	$15,000.00	$15,000.00
19	REASSEMBLE/ ERECT BRIDGE SUPERSTRUCTURE	LUMP SUM	1	$100,000.00	$100,000.00
20	COMMON EXCAVATION	CU YD	650	$18.00	$11,700.00
21	SELECT GRANULAR BORROW MOD 7%	CU YD	250	$32.00	$8,000.00
22	CLASS V AGGREGATE BASE	CU YD	300	$42.00	$12,600.00
23	EROSION CONTROL ETC	LUMP SUM	1	$20,000.00	$20,000.00
24	NEW BRIDGE SIGNAGE	LUMP SUM	1	$5,000.00	$5,000.00
25	SITE WORK AND RESTORATION AT OLD LOCATION	LUMP SUM	1	$30,000.00	$30,000.00
	20% CONTINGENCY	LUMP SUM	1	$208,000.00	$208,000.00
ESTIMATED REHABILITATION COST					**$1,243,790.00**

Option 4: Remove/ dis-assemble bridge from existing location and ship to off-site location for storage

KERN BRIDGE, REHABILITATION OPTION STUDY ESTIMATE (2017 DOLLARS)
OPTION 4: REMOVE/ DIS-ASSEMBLE BRIDGE FROM EXISTING LOCATION AND SHIP TO OFF-SITE LOCATION FOR STORAGE
August 31, 2017

			ESTIMATED QUANTITIES AND COST		
ITEM NO.	ITEM	UNIT	QUANTITY	UNIT COST	TOTAL ESTIMATE
OPTION 4: REMOVE/ DIS-ASSEMBLE BRIDGE FROM EXISTING LOCATION AND SHIP FOR STORAGE AT OFF-SITE LOCATION					
1	MOBILIZATION	LUMP SUM	1	$30,000.00	$30,000.00
2	DISMANTLE TRUSS/ARCH SUPERSTRUCTURE	LUMP SUM	1	$160,000.00	$160,000.00
3	TRUCKING OF STEEL COMPONENTS TO STORAGE FACILITY	LUMP SUM	1	$15,000.00	$15,000.00
4	SITE WORK AND RESTORATION AT OLD LOCATION	LUMP SUM	1	$30,000.00	$30,000.00
	15% CONTINGENCY	LUMP SUM	1	$36,000.00	$36,000.00
ESTIMATED DIS-ASSEMBLE & TRANSPORT COST					**$271,000.00**

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Appendix A. Guidelines for Bridge Maintenance and Rehabilitation based on the Secretary of the Interior's Standards

The Secretary's Standards with Regard to Repair, Rehabilitation, and Replacement Situations

Adapted from:

Clark, Kenneth M., Grimes, Mathew C., and Ann B. Miller, *Final Report, A Management Plan for Historic Bridges in Virginia*, Virginia Transportation Research Council, 2001.

The Secretary of the Interior's Standards for the Treatment of Historic Properties, first codified in 1979 and revised in 1992, have been interpreted and applied largely to buildings rather than engineering structures. In this document, the differences between buildings and structures are recognized and the language of the Standards has been adapted to the special requirements of historic bridges.

1. Every reasonable effort shall be made to continue an historic bridge in useful transportation service. Primary consideration shall be given to rehabilitation of the bridge on site. Only when this option has been fully exhausted shall other alternatives be explored.

2. The original character-defining qualities or elements of a bridge, its site, and its environment should be respected. The removal, concealment, or alteration of any historic material or distinctive engineering or architectural feature should be avoided.

3. All bridges shall be recognized as products of their own time. Alterations that have no historic basis and that seek to create a false historic appearance shall not be undertaken.

4. Most properties change over time; those changes that have acquired historic significance in their own right shall be retained and preserved.

5. Distinctive engineering and stylistic features, finishes, and construction techniques or examples of craftsmanship that characterize an historic property shall be preserved.

6. Deteriorated structural members and architectural features shall be retained and repaired, rather than replaced. Where the severity of deterioration requires replacement of a distinctive element, the new element should match the old in design, texture, and other visual qualities and where possible, materials. Replacement of missing features shall be substantiated by documentary, physical, or pictorial evidence.

7. Chemical and physical treatments that cause damage to historic materials shall not be used. The surface cleaning of structures, if appropriate, shall be undertaken using the most environmentally sensitive means possible.

8. Significant archaeological and cultural resources affected by a project shall be protected and preserved. If such resources must be disturbed, mitigation measures shall be undertaken.

9. New additions, exterior alterations, structural reinforcements, or related new construction shall not destroy historic materials that characterize the property. The new work shall be differentiated from the old and shall be compatible with the massing, size, scale, and architectural features to protect the historic integrity of the property and its environment.

10. New additions and adjacent or related new construction shall be undertaken in such a manner that if removed in the future, the essential form and integrity of the historic property and its environment would be unimpaired.